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Economic Aspects of Foamed Adhesives Using in Wood Processing Industry

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Abstract

In today´s competitive business fight each company try to optimize its costs. Cost optimization is an important role for all of the companies. This fact also can be apply for the companies operates in wood processing industry. In the wood processing industry play adhesives important role and they are important secondary materials in furniture industry also. Adhesives significantly contribute to improving the products quality and they are also the basis for the development of new improved wood products. The main goal of the article is to promote the possibility of foamed adhesives using as a chance for the costs saving during the production of solid wood panels. The methods of our research are focused on the increasing of adhesive volume by foaming technology using the standard STN 13 354. Just through this technology adhesive can be applied to the bonding area more efficiently. It creates opportunities for applying of less volume of adhesive in bonded joints and on the other hand for obtaining the comparable strength requirements as the conventional volume of un-foamed adhesive. Based on our results it is possibility to reduce dispersion adhesive volume at 22%. From our research can be conclude that adhesives foaming is a technology that allows achieving the desired bonding strength at significantly reduced spread rate of adhesives and has also positive economic aspects in the production. Cost savings can be strong competitive advantage for plenty of companies.

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1. Introduction

The technology of wood bonding is one of the essential technological operations changing wood shape and dimensions. Hass P., et al. (2011) wood bonding significantly participates in improving the quality of products and it is also one of the cornerstones in the development of new wood products. This complex process should result in the creation of good and strong adhesive bond. Sujová, A., et. al. (2015) wrote, that in the foreign trade in wood processing industry have adhesive for wood bonding significant impact and an important role in the production of solid wood panels. The wide range of factors affects the quality of adhesive bond. Several types of adhesives are used for wood bonding.

However, nowadays dispersion adhesives are the most used for wood bonding. Kurt R. (2006) the importance of dispersion adhesives is increasing continually. Adhesives foaming start to be highly discussed sphere in the production of wood based materials. Through the increasing of adhesive volume by foaming technology, adhesive can be applied to the bonding area more efficiently and it creates opportunities for cost saving effects during the production (reduction of direct used material by reducing the amount of applied adhesive). Potkány M., Hitka M. (2009) the cost savings play importance role in the company competitiveness in present.

With adhesives foaming, resp. urea-formaldehyde adhesives (UF) for bonding process of plywood and chipboard have many authors dealt since the 80´s of the 20th century, as evidenced by the scientific works of WATTERS and WELLONS, published in Forest Products Journal in year 1978 as well professional articles from SELLERS, which have also been published in Forest Products Journal in 1988. In 1994 a group of American scientists gave invention of foaming urea-formaldehyde adhesives for the production of chipboard patented.

Foaming of dispersion adhesives with air enable to increase its total volume, the adhesive may be applied into a glue-line more efficient and more uniform. Foaming PVAc dispersion adhesives is a relatively new field of research. Currently, the technology of foaming dispersion adhesives proved far especially in the lamination and gluing cartons. Sedliačik J., et. al. (2011) the adhesive foaming is the focal point of scientific debates in the wood industry and the furniture manufacturing because of rapidly increasing customer requirements for product quality and necessity of the manufacturing cost reduction. Adhesive foaming creates the conditions for achieving cost-efficient coatings of adhesive applied into the glued joints while achieving comparable strength of the bond in comparison with un-foamed conventional adhesive bonded joints. Foaming of adhesive is a technology that provides the ability to achieve the required bonding strength at reduced adhesive spread and thereby can bring positive economic aspects in the production of solid wood panels.

The basic goal of our research is to find the optimal volume of PVAc dispersion which is using during the production of solid wood panels. On the basis of our previous researches it is well known fact, that the best properties have the dispersion adhesives foamed at 30% of its volume. Based on these findings we try to vary different adhesive volumes in this research (totally 7 different volumes). Just through these steps in the primary goal of this paper to find the optimal volume of using adhesive where the bonded joints meets the criteria of the Standard STN EN 13 354 which describes the requirement for quality of bonded joints. In the present is in the production of solid wood panels use the volume of dispersion adhesive 180 g/m^2 of unfoamed adhesives. We try to describe in this paper, based on our research, that there is a possibility to reduce adhesive volume by foaming technology and it has a great economics aspects in the production by cost savings.

Advantages of using foamed dispersion PVAc adhesive in the gluing process can be summarized as follows:

- good wetting of the adherent surface – due to better and more uniform adhesive spread;
- weaker, resp. slower penetration of water from glue into the cells of wood – due to lower adhesive spread and cohesive bonds between air micro-bubbles resulting in better ensuring the flat stability of the panel and increase the quality at the interface wood – adhesive;
- cost savings – in the bonding process, there is a reduction of direct used material by reducing the amount of applied glue;
- no formaldehyde emissions.

2. Material and Methods

As it was written, the conventional spread of dispersion in the production of solid wood panels is at the level 180 g/m^2. In our research the adhesive bonds strengths were evaluated in order to ***7 levels of foamed adhesive amount*** in glue line (100 g/m^2, 110 g/m^2, 115 g/m^2, 125 g/m^2, 140 g/m^2, 160 g/m^2, 180 g/m^2).

Adhesive - one component PVAc dispersion, type RAKOLL® 4340, with perfect water resistance (class D4 according to EN 204) were tested with the aim to find optimal amount of applied adhesive. This type of adhesive was specially developed for application in the micro-foam state. In our research was used adhesive foamed at 30% of its volume.

According to the standard EN 13354: 2009 Solid wood panels (SWP). Bonding quality. Test method. there was tested quality of gluing. Based on the standard requirements, it was necessary from each tested batch, resp. from each panel to prepare testing samples for minimally 10 valid values from different adhesive amount (70 testing samples together). Preparing of testing samples, the shape and dimension, is illustrated in the following Fig. 1:

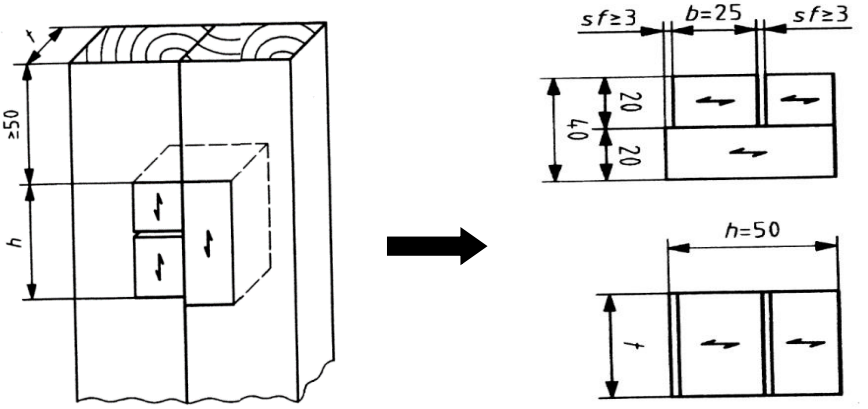

Fig 1. Preparing of testing sample.

The requirements of standard STN EN 13 354 have specified, that the principle of shear test is based on the pre-treatment of the testing samples in the thermostatic bath. All 70 testing samples were dipped in a water bath for 24 hours at the water temperature T = (20 ± 3)°C. Based on STN EN 13 353: 2009, the required strength of the glued joint is expressed by lower 5% percentile from measured values on the level over 2,5 MPa.

Information obtained by measuring of all test pieces was evaluated by selected tool of mathematical statistics. The results of all our measurements were summarized and statistically evaluated by using the program STATISTICA 12 and mathematical software Wolfram Mathematica 7.0. Through the regression analysis we need to estimate the relationship among variables (adhesive spread, adhesive strength). In all cases, the estimation target will be a function of the independent variables called regression function, in our paper.

Based on the estimated savings of used adhesive it was made a brief calculation of cost savings. Technology for adhesive foaming consists from the technological equipment in the price 37 000 EUR (IC – invested capital). On the modeled example in selected company we try to evaluate the investment efficiency of foaming technology through the formula - IR (index of rentability):

$$IR = \frac{Total\ NPV}{IC} \tag{1}$$

In this paper we also try to evaluate the efficiency of the investment through the formula - DPP (discounted payback period) on the modeled example in selected company:

$$DPP = \frac{IC}{\emptyset NPV} \tag{2}$$

3. Results and Discussion

The results of our measurements were aimed at the verification of the assumption, that increasing of the dispersion volume by foaming enables to spread the adhesive on the surface more uniform with a better quality, but also the effect of saving is achieved.

Based on obtained results (7 different adhesive spreads x 10 testing samples in each spread), we counted the dependence of the shear strength (Y) on the glue spread (X) within the interval <100 g/m2; 180 g/m2> by the mathematic function as is illustrated in the following Fig. 2:

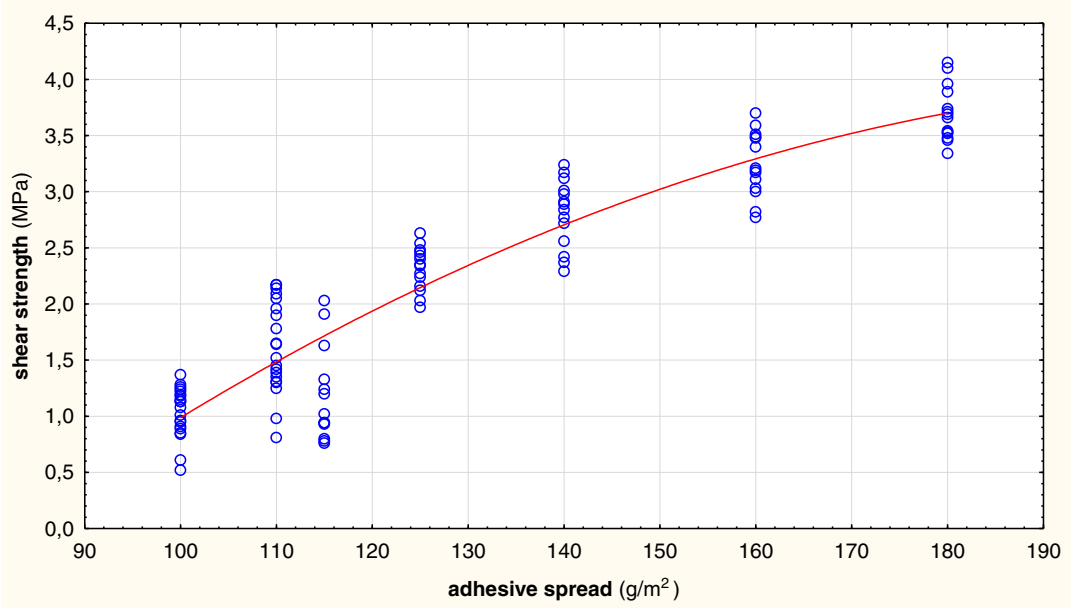

Fig. 2. Regression analysis.

The statistical significance of parameters and model as a whole, as well as the adequacy of the model was verified. The results showed that all of the parameters are statistically significant and adequate. The equation of the regression line had the form:

$$y = - 6,7262 + 0,0972*x - 0,0002*x^2 \quad (3)$$

On the basis of homogeneity of the variance in the residual component we have calculated and converted mentioned above quadratic equation by using mathematical program Wolfram Mathematica 7.0. Based on the obtained results, we can assume that the samples with application of 30 % of foamed adhesive RAKOLL® 4340 with the ***adhesive spread of 140,51 g/m^2 can be achieved such shear strength where the lower 5 % percentile is on the level of 2,5 MPa.***

From the evaluation of the results, we can conclude, that the adhesive spread oscillating around 140 g/m^2 of used dispersion adhesive, which is foamed up to 30 % of its volume. In this adhesive spread should be achieved such shear strength of samples which meets the requirements of the EN 13 353: 2009 Solid Wood Panels (SWP). Requirements. The average consumption in the conventional dispersion adhesive spread is 180 g/m^2. Through our research we can conclude that if we use dispersion adhesive foamed at 30% of its volume (with the level of water resistance D4) there can be achieved the adhesives savings at the level of 40 g/m^2. It is approx. 22% of total used adhesive volume. This fact brings the positive economic aspect in the production of solid wood panels. There is a reduction of direct material by reducing the amount of applied adhesive (lower direct costs) and it can has also positive impact to the reduction of indirect costs (costs for storage, transportation…). For the production of 1 m^3 of

solid wood panel is used in an average of 8,50 kg of adhesive. In the following Table we try to calculate the savings of direct costs of the production:

Table 1. Direct cost saving.

Adhesive type	Adhesive consumption	Adhesive price	Total costs
Rakoll foamed 30 %	6,61 kg/m^3	1,75 EUR/kg	11,57 EUR
Rakoll unfoamed	8,50 kg/m^3	1,75 EUR/kg	14,88 EUR
TOTAL DIRECT COST SAVINGS per m^3			3,31 EUR

For adhesive foaming is a need to procure technological equipment which is able to foam the adhesive is of a desired percentage of the air volume. The cost of process equipment, including costs related to the acquisition and installation, moves approximately EUR 37 000, -.

However, the question is what should be the minimum volume of company´s production, if we want to return the initial investment of 37 000 EUR for the acquisition of such technological equipment, which is capable of adhesives foaming. Based on information from the company Rettenmeier Tatra Timber Ltd. is known fact that the average annual production of solid wood panels is about 10 000 m^3 in this company. For a practical demonstration of the effect of cost savings to net present value (NPV) we used a brief presentation on following short case study. We calculated NPV during 6 years – the official, based in the Act 595/2003 Law on Income tax, length of technology life cycle. We describe the input parameters when using adhesives RAKOLL® 4340 (D4) on the acquisition of technological equipment capable of ensuring the foaming process of glue:

- maximum annual producing 10 000 m^3
- the current annual production of 8 000 m^3
- the effect of cost saving by foamed adhesive using (8 000 m^3 * EUR 3.31 / m^3)

In Table 2, we calculate the total NPV of an investment at a discount rate of 7% as follows:

Table 2. Calculation of total net present value when using adhesives RAKOLL® 4340.

YEAR	1.	2.	3.	4.	5.	6.
Effect form cost savings (EUR)	26 480,-	26 480,-	26 480,-	26 480,-	26 480,-	26 480,-
Discount (7%)	0,9346	0,8734	0,8163	0,7629	0,7130	0,6664
NPV (EUR)	27 748,21	23 127,63	21 615,62	20 201,59	18 880,24	17 646,27
Total NPV (EUR)	129 219,56					

As we can conclude from the short calculation, in above Table 2, total NPV for 6 year technology life cycle is 129 219,56 EUR. Through following formulas (IR, DPP) we can verify, if such investments can be profitable for this company:

$$IR = \frac{TotalNPV}{IC} = \frac{129219,56}{37000} = 3,49 \quad (4)$$

Index of rentability (IR) is 3,49. It means that the initial investment EUR 37 000,- is profitable at 349% during the official 6 years technology life cycle. And discounted payback period is less than 2 year, as it is calculated through the following formula (5):

$$DPP = \frac{IC}{\phi NPV} = \frac{37000}{\frac{129219,56}{6}} = 1,72 \quad (5)$$

4. Conclusion

Kurt, R. (2006) wrote that there is a strong correlation between the thickness of the bonded joint and adhesive shear strength. Thick spread of adhesive to glue-line was also concerned by Budakci, M. (2010). His conclusive studies indicate that there is very little difference at the level of 4% between the average bond strength in the samples with spread with PVAc adhesive of 200 g/m^2 and debris 150 g/m^2. And that is why dispersion adhesives with spread of 150 g/m^2 may still be considered sufficient, given the conditions the efficient use of input material.

Based on our results, we can conclude that the foaming of dispersion adhesives can optimize the amount of applied adhesive in gluing process in the production of solid wood panels. Our results are reflected in the finding that foaming of PVAc dispersions leads to the reducing its consumption. The practical benefit of the research from the technological point can be expected within the optimisation of wood gluing processes, with the aim to ensure such production assumptions, which will bring effective minimisation of the production costs at required quality level. Researched dispersion adhesive (water resistance D4) was foamed at 30% of its volume by air. The adhesive consumption saving was approx. 22% of used PVAc adhesive. The initial investment for the procuration of the technology for adhesive foaming is EUR 37 000, -. Through short analysis of the production capacity in company Rettenmeier Tatra Timber Ltd., which belongs to the one of the biggest Slovak companies operate in wood processing industry, we can conclude, that such investment is profitable during its life cycle. Based on the result of formula (3, 5) we can also conclude that investment will be returned during 1 year and 9 months.

Final effect from the economic view can be expected in an effort to at least partially manage the production costs and maintaining a strong link between the quality characteristics of the final product, technology, production costs and the final price of the product, which can create a strong competitive advantage for the companies with the higher production volumes, mainly in the wholesale.

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